

# PLANiTS

## Structuring and Supporting the Intelligent Transportation Systems Planning Process

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PLANiTS (Planning and Analysis Integration for Intelligent Transportation Systems) is a process-based computer system that supports a series of mutually interdependent steps progressing toward developing and programming transportation improvement projects. It is a tool that translates problems and goals to performance measures, examines possible competing and complementary transportation improvement actions, systematically evaluates the impacts of actions using models and knowledge, and supports human interactions between stakeholders. The PLANiTS methodology is nonincremental because it integrates existing knowledge about transportation with analysis using models with deliberation and issue resolution. To link planning and modeling, PLANiTS has a policy base that contains contemporary performance measures, an action base containing conventional and Intelligent Transportation Systems actions, a methods base that facilitates modeling, a case that has qualitative and quantitative information about historical cases, and a set of computer-based communications tools. This comprehensive methodology will likely expedite the implementation of intelligent technologies by systematically examining their trade-offs with more conventional transportation improvement actions. PLANiTS's structure, functionality, and application are described. Transportation improvement projects are represented as planning vectors in PLANiTS. A vector permits users to examine the effects of chosen transportation actions in terms of performance measures within an environment. Users must specify the actions, performance measures, and the environment, each in terms of their spatial, temporal, and user dimensions. Then they can analyze the planning vector with models and case-based reasoning. During the process of planning vector specification and analysis, stakeholders at different locations can communicate by sending and receiving messages and sharing the planning vector. Users at different locations can examine and review the results and iterate in an open and deliberative planning environment. Overall, PLANiTS facilitates transportation planning processes by combining analysis and deliberation.

Urban transportation problems persist and are increasing in their complexity and scope. Traffic congestion, pollution, and safety problems are a part of daily life. Whereas these problems may be acceptable at certain levels, their current levels are high. Lawmakers have approved legislation such as the Intermodal Surface Transportation Efficiency Act (ISTEA) and the Clean Air Act to curtail the harmful effects of travel and to fund projects that address broader policy goals. New transportation technologies offer solutions to these problems; however, inappropriate technology implementation can sometimes worsen them. Therefore, a planning methodology that seeks to address important transportation problems needs to be open and policy-relevant.

Although new transportation technologies offer opportunities, there is a gap between their development, assessment in a specific context, and proper implementation. Importantly, in transportation planning, there is a complex and often muddled political process that precedes the implementation of transportation projects. The "planning problem" is made complex by the difficulty of involving various stakeholders in transportation project planning, the intricacy of the analytical processes, the lack of systematic knowledge bases, and the difficulty of setting up real-time deliberative and negotiation processes.

To implement intelligent transportation technologies, a key element is being able to identify Intelligent Transportation System (ITS) opportunities in the planning process. It is likely that intelligent transportation technologies will not dominate the planning process. Rather, they may act as catalysts for change. Any new planning methodology should permit stakeholders to examine trade-offs among ITS and conventional transportation actions, evaluate impacts and benefits, and sharpen insights in an interactive environment. The implementation of new transportation technologies is complicated partly because they must be eased into the existing transportation system. This often promotes the status quo and encourages incrementalism—hampering innovative new approaches. However, to address problems comprehensively, any new planning methodology must enhance creativity in exploring innovative solutions.

To support the emerging transportation planning processes and facilitate ITS implementation, a new planning methodology should integrate the structured methods (i.e., transportation planning and operational models) with semistructured analysis techniques such as knowledge-based systems and unstructured electronic decision support. A methodology called PLANiTS, which stands for Planning and Analysis Integration for Intelligent Transportation Systems, was proposed for this purpose (1,2). Whereas structured analysis and modeling have been used widely in transportation planning, their integration in an open and deliberative planning environment supported through computer dialogue is an innovation made possible by PLANiTS. To address transportation problems, PLANiTS offers expanded opportunities for considering alternative strategies (e.g., synergies among new technologies). The earlier work focused on developing the conceptual structure for PLANiTS (1,2). This paper reports on structuring of PLANiTS concepts and their translation into a practical tool that can support a real-life transportation planning process. The planning support comes from being able to run sophisticated models and access quantitative and qualitative information through case-based reasoning and intelligent data bases. Importantly, stakeholders can make transportation plans interactively in PLANiTS.

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This paper presents the PLANiTS structure and a simple model of PLANiTS. The model can demonstrate key PLANiTS functions (3). The proposed transportation projects are represented as planning vectors in PLANiTS. Through the planning vector, stakeholders can select transportation improvement actions from an action base, performance measures from a policy base, and the environment from the data base. They can then use the case-based reasoner or the model base to evaluate the impacts of actions contained in the planning vector. During the analysis process, PLANiTS users can deliberate by sending and receiving text messages and by sharing their planning vectors. The model can demonstrate a transportation planning cycle from project proposal development, to analysis, to deliberation, and back to changing the project specifications.

## CONSIDERATIONS IN PLANiTS DESIGN

The PLANiTS methodology is based on the following considerations:

- Transportation planning processes involve (a) policy direction usually provided by state and federal agencies, (b) project generation that often occurs at local and regional levels and (c) project selection that occurs at regional, state, and federal levels. Project selection is often muddled and political.
- In addition to mobility, environmental concerns increasingly are driving the transportation planning process. Moreover, transportation plans are now considered legal documents that should specify how the stated goals will be achieved (they are not merely guidelines).
- New strategies to address environmental concerns include encouraging transportation control measures and delaying projects that harm the environment. In view of these broader evaluation criteria, ITS actions must be evaluated vis-a-vis conventional transportation improvement actions.
- Plans, data, and models increasingly are open to scrutiny by stakeholders. Furthermore, the technical portion of transportation planning is based on the four-step modeling process that is not sensitive to the emerging technologies. Also, transportation planning models are not value-neutral and sometimes incorporate developer biases. In the planning process, analysis conducted with state-of-the-art models can often be challenged on various grounds, both technical and nontechnical.

In view of these considerations, PLANiTS was designed to present relevant information to stakeholders, analyze the effects of transportation improvement actions, and facilitate stakeholder communication. The PLANiTS methodology

- Is policy-sensitive and allows stakeholders to iterate in steps that eventually lead to project development and specification.
- Integrates state-of-the-art models with appropriately synthesized knowledge-based tools to address a broader set of evaluation criteria. Stakeholders can examine the trade-offs between ITS and conventional transportation improvement actions by using models and knowledge-based tools.
- Supports group interactions and opens technical issues to debate and critique. Using PLANiTS, stakeholders can agree on model assumptions and data types before conducting analysis. The support comes as a computer-based dialogue about the data, models, and

their results. Linked modeling and deliberation systems could enhance creativity through expanded sets of actions and evaluation criteria.

## PLANiTS COMPONENTS

The PLANiTS architecture, developed during the earlier stages of the study, is based on two fundamental processes: supporting analysis and group interactions. Analysis includes using not only models but also intelligence and qualitative information. Group interactions include deliberative planning, issue resolution, and project programming. These are supported through various bases described by Kanafani et al. (1) and discussed briefly here (Figure 1):

- The Policy and Goals Base contains mandates, objectives, and constraints communicated in terms of appropriate policy factors to be satisfied and measures of performance. It also has a set of rules that link policies to performance measures and actions.
- The Strategy and Action Base contains a catalog of possible actions and rules that inform users about synergies among actions.
- The Data and Knowledge Base contains and provides access to data bases and has knowledge in terms of theoretical and empirically established relationships between transportation objects; it also contains cases and the case-based reasoning mechanism.
- The Methods and Tools Base contains specific and generic transportation models.

These bases are handled by various agents. Moreover, the process of group interaction is supported through a set of building block functions handled by the deliberation tool. Each component of the architecture is developed while deliberation and issue resolution are allowed to occur at all stages.

The glue that binds PLANiTS components and supports the deliberative planning and analysis processes is the planning vector (PV), which contains three subvectors:

- Action vector, *A*, includes the proposed actions that are the subject of the planning process;
- Criteria vector, *Y*, includes the measures of performance representing the goals for which the actions are proposed; and
- Environment vector, *E*, includes the descriptors of the context that are relevant to the subject actions and impacts.

Thus, the planning vector  $PV = [A, Y, E]$ .

Actions and performance measures each have a hierarchy and are specified in terms of their spatial, temporal, and user dimensions. The hierarchy facilitates the search for appropriate models and historical cases (4), and the specification of the PV by stakeholders provides the data needed to run models and retrieve similar historical cases.

The authors use the examples of high-occupancy vehicle (HOV) lanes and advanced transportation management and information systems (ATMIS) throughout this paper. The HOV example was chosen because such lanes constituted a large portion of the recent planning projects in California and they can potentially integrate new technologies (e.g., real-time rideshare matching systems). Also, priority for certain vehicles is the basis for automated highway systems (AHS), in which laterally and longitudinally controlled vehicles will travel faster than others. The ATMIS example is appropriate because

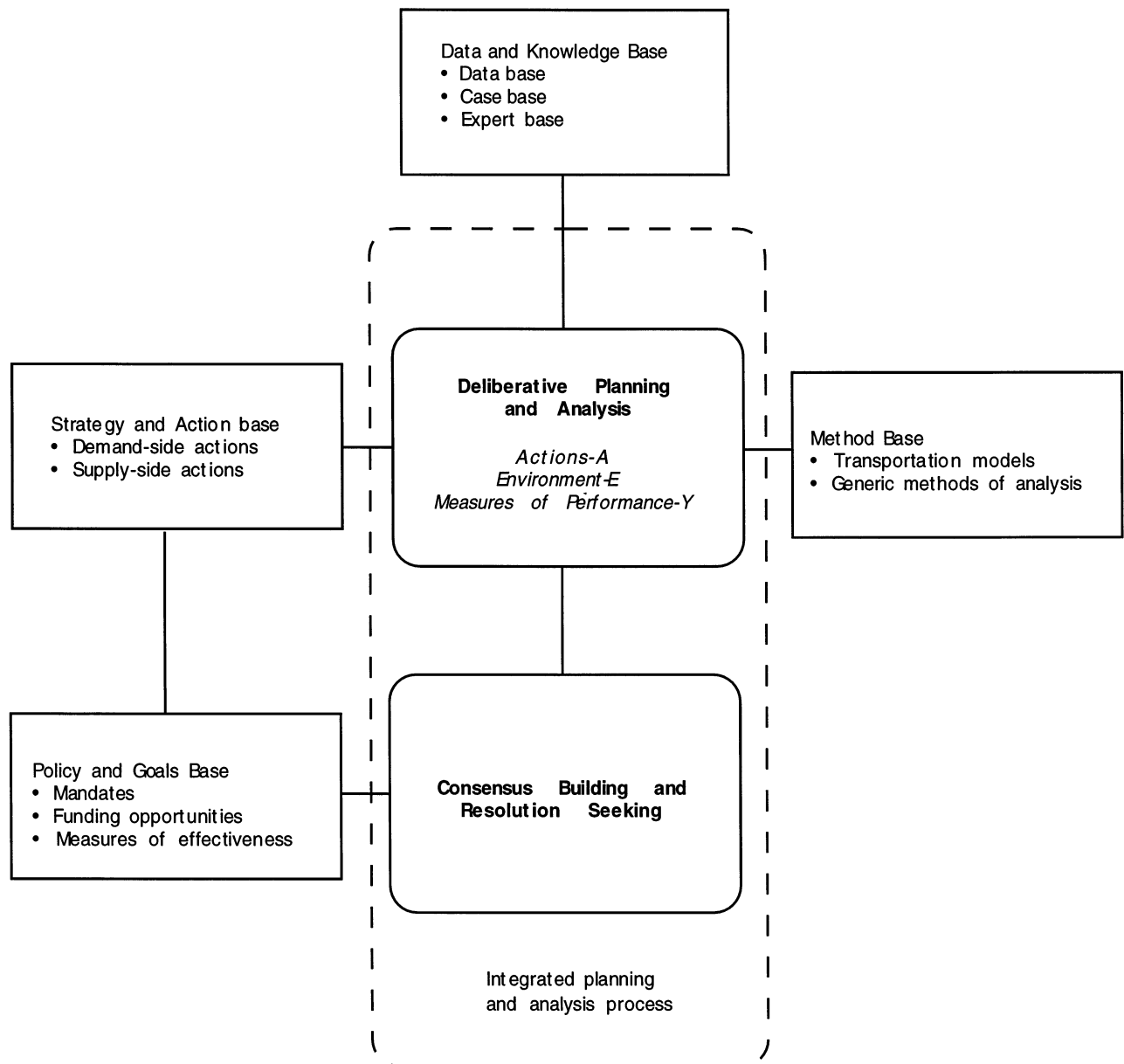


FIGURE 1 PLANiTS components (I).

it represents a set of new technologies that are closest to deployment. Moreover, there is some experience with precursor ATMIS and HOV technologies that is useful in demonstrating the PLANiTS knowledge base and methods base. Taken together, the two examples can demonstrate the trade-offs faced by stakeholders when selecting between relatively conventional HOV lane actions and new ITS actions.

## PLANiTS STRUCTURE

PLANiTS represents data and cases according to a structure that facilitates evaluation through modeling and case-based reasoning. Transportation improvement actions and performance measures each have a hierarchy (Figure 2). In PLANiTS, historical cases and

data are indexed according to cluster, subcluster, and descriptor levels. Define actions,  $A_{j|i}$  where  $i$  describes the action clusters,

$\{\text{roadway, transit, bicycle/pedestrian, intermodal/freight}\} \in i$

and  $j$  describes a specific planning action (subcluster level) implemented on  $i$ ,

$\{\text{HOV, bus priority, ATMIS, transit information system}\} \in j$

so that

$\{\text{HOV|roadway, bus priority|transit,}$

$\text{ATMIS|roadway, transit information system|transit, } \dots \} \in A_{j|i} \quad (1)$

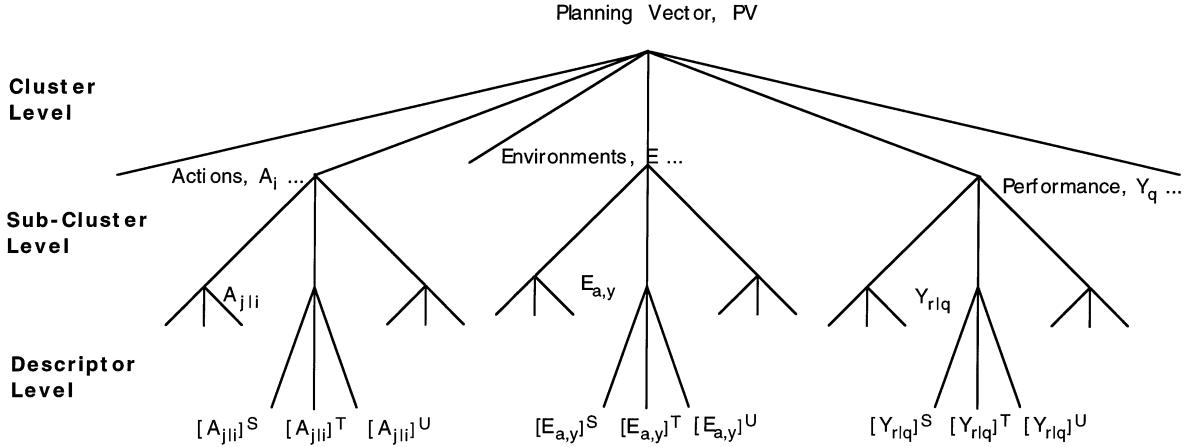


FIGURE 2 Planning vector structure (4).

Actions are specified in terms of three fundamental descriptors:

$$[\text{HOV}|\text{roadway}]^{S_1, \dots, S_k T_1, \dots, T_l U_1, \dots, U_m} \in [A_{ij}]^{S', T', U'} \quad (2)$$

where

- $S'$  = spatial descriptors;
- $S_1$  = length of HOV lanes (sum of HOV link lengths);
- $S_2, S_3$  = number of mixed-flow and HOV lanes, respectively;
- $S_4$  = whether HOV and mixed-flow lanes are physically separated;
- $T'$  = temporal descriptors;
- $T_1$  = a.m. time of HOV lane operation;
- $T_2$  = p.m. time of HOV lane operation;
- $T_3, T_4$  = travel times on HOV and non-HOV links;
- $U'$  = user descriptors;
- $U_1$  = vehicle occupancy threshold for HOV eligibility;
- $U_2$  = amount of HOV lane violation fine incurred by non-eligible motorists (\$);
- $U_3$  = traveler decision whether to travel during HOV lane operation times; and
- $U_4$  = traveler decision whether to share a ride (for HOV lane eligibility).

Notice that  $S$ ,  $T$ , and  $U$  operate only at the  $j|i$  level—that is, the spatial, temporal, and user descriptors can be defined only after a specific planning action  $j$  is chosen. For the ATMIS example, the descriptor level specification is

$$[\text{ATMIS}|\text{roadway}]^{S_1, \dots, S_k T_1, \dots, T_l U_1, \dots, U_m} \in [A_{ij}]^{S', T', U'} \quad (3)$$

where

- $S_1, S_2$  = two parallel network links (main and alternative routes) that are monitored through surveillance technologies;
- $S_3, S_4$  = normal capacities of links;
- $S_5, S_6$  = reductions in capacities on the two links due to incidents;
- $T_1, T_2$  = free-flow travel times on two links;
- $T_3, T_4$  = average incident durations on each link;
- $T_5, T_6$  = average response times for patrol vehicles on the two links;
- $U_1$  = user decision whether to travel during certain times;
- $U_2$  = user decision whether to access advanced traveler information devices, and

$U_3$  = user decision whether to divert to alternative routes in response to congestion.

The total number of items (cases or observations) stored in a particular data base is  $n$ . Therefore, the action for each case or observation is denoted by  $[A_{j|i}]^{S', T', U'}$ .

Performance measures are defined by  $Y_{r|q}$ . Here  $q$  describes the performance clusters,

{congestion, air quality, safety, accessibility, noise, ...}  $\in q$

and  $r$  describes a specific performance measure that relates to  $q$ ,

{person-delay, travel time, carbon monoxide, nitrogen oxides, ...}  $\in r$

Therefore, a tree structure can be represented as

{person-delay|congestion, carbon monoxide|air quality, ...  
travel time|congestion, nitrogen oxides|air quality, ...}  $\in Y_{r|q}$

The performance measures are defined at the descriptor level as follows:

$$[\text{person-delay}|\text{congestion}]^{S_1, \dots, S_d T_1, \dots, T_l U_1, \dots, U_f} \in [Y_{r|q}]^{S', T', U'} \quad (4)$$

where

- $S'$  = spatial descriptors: links  $S_1, \dots, S_d$  where person delay was measured/estimated in the HOV lane historical case (these links may be different from the links where the HOV lane operates);
- $T'$  = temporal descriptors;
- $T_1$  = person delay (measured or estimated) during the a.m. HOV lane operation;
- $T_2$  = person delay during p.m. HOV lane operation; and
- $U'$  = user descriptors: delay experienced by HOV eligible and noneligible travelers.

For the ATMIS example, the specification is

$$[\text{average delay per vehicle}|\text{congestion}]^{S_1, \dots, S_d T_1, \dots, T_l U_1, \dots, U_f} \in [Y_{r|q}]^{S', T', U'} \quad (5)$$

where

- $S_1, S_2$  = average delay per vehicle on two network links that are monitored through surveillance technologies;
- $T_1, T_2$  = average queue durations on network links that are monitored;
- $T_3, T_4$  = average delays per person during peak and off peak, respectively; and
- $U_1, U_2$  = average delays per vehicle for travelers equipped and not equipped with information devices.

The performance measure portion of each case  $n$  is denoted by  $[Y_{r/q}]^{S,T,U'}$

The environment,  $E_{a,y}$ , is the backdrop where actions are implemented and system performance impacts estimated or measured. Descriptions of the  $E_{a,y}$  are partly contained in actions and performance measures. The environment defines more generally where and when the action was implemented and who was affected. The environment is defined in terms of spatial, temporal, and user descriptors. Therefore,  $[E_{a,y}]^{S,T,U'}$  indicates the context for a specific action and its impacts. For example,

- $S_1, S_2$ , and  $S_3$  indicate, respectively, the country, state, and city where the case or observation was implemented or data were collected. This definition of the environment facilitates PLANiTS processes such as case matching and model selection.
- $T_1$  and  $T_2$  represent, respectively, the time when the historical case was implemented or observations obtained and the maturity of the technology at the time of implementation.
- $U_1, U_2$ , and  $U_3$  indicate, respectively, the population characteristics of density, demand for transportation facilities, and income in the area under consideration.

Typically, models use action and environment vectors to evaluate (EVAL) impacts. Symbolically,

$$\{[A_{j/i}]^{S',T',U'}[E_{a,y}]^{S,T,U'}\} \quad \text{EVAL} \quad [Y_{r/q}]^{S',T',U'} \quad (6)$$

PLANiTS will ultimately contain many models, indexed according to the PV structure. If users choose to evaluate a specified current planning vector,  $PV_c$ , then the methods base will search for appropriate models by matching at the cluster, subcluster, and descriptor levels. The matched models will be presented to users. The selected models will be able to assess the impacts of user-specified actions in terms of performance criteria at the desired levels of disaggregation. For example, if a group of stakeholders is interested in evaluating the effect of ATMIS on traffic in their neighborhood, then they could choose a model that estimates the magnitude of diverted traffic on specific neighborhood links. Alternatively, there may be no model in PLANiTS that estimates traffic at the neighborhood level.

The selection of historical cases proceeds by defining the distance  $D$  between a historical case  $n$  contained in the data base and the current case  $c$  reflected in the specification of the active planning vector (4):

$$D(n, c) = \text{difference } (PV_n, PV_c) \quad (7)$$

where PV denotes the chosen planning vector elements. Therefore,

$$D(n, c) = \begin{cases} 0 & \text{if } PV_n = PV_c, \text{ i.e., when } A_n = A_c, E_n = E_c, Y_n = Y_c \\ 1 & \text{otherwise} \end{cases} \quad (8)$$

where A, E, and Y denote the action, environment, and performance measures, respectively. The retrieved historical cases must match on the elements of the user-specified planning vector PV at the appropriate cluster, subcluster, or descriptor level.

## DESCRIPTION OF PLANiTS PROCESS

Stakeholders can begin a PLANiTS session by either connecting to a currently running planning session through a network or beginning a new session. All computer communications occur in real-time, so at least two groups at different locations can interact and work jointly on one planning vector. Stakeholders can perform the following processes in PLANiTS:

- *Select project type.* Projects typically belong to certain categories; for example, they can be roadway, transit, bicycle/pedestrian, or intermodal/freight. Stakeholders decide on the relevant transportation improvement actions.
- *Select goals to be achieved.* The goals and policies translate to more specific performance measures that must be calculated.
- *Select the environment.* The environment specification requires that the project boundaries and the data used for analysis be identified.
- *Choose appropriate methods for evaluation.* The users can select appropriate model- and knowledge-based tools for evaluation.
- *Compare evaluation results.* Stakeholders can compare the changes in performance measures before and after implementing various actions.
- *Interact with other stakeholders.* Users can debate, review, and rereview aspects of the planning process.

Assume that stakeholders decide to develop and analyze a new planning vector. They begin working on the planning vector list by adding and removing elements after creating and naming it. The vector must have at least one of each (action, performance measure, and environmental descriptors) before evaluation can begin. Stakeholders can fill in the planning vector by choosing elements from (menu) lists.

A novel way to add elements to the planning vector is to define the context. The context is defined by participant's agency (congestion management agency, city, county, transit agency, regional transportation planning organization, citizens' group) and the policy of interest. This and additional information are used to provide intelligent advice in constructing the planning vector. For example, if PLANiTS users indicate that certain policy factors should be included, then PLANiTS can suggest performance measures. Stakeholders can choose among the policies of interest that include ISTEA, the Clean Air Act, and the Americans with Disability Act. For ISTEA, a list of the 15 factors appears. If stakeholders select congestion relief from the checklist, then PLANiTS suggests that alternative congestion measures such as delay and travel time be used for evaluation. Stakeholders can accept or override suggestions. Of course, the contents of the planning vector are subject to debate and review. Similarly, if stakeholders show interest in ITS, then ATMIS is suggested.

PLANiTS users proceed with constructing and refining the planning vector. Stakeholders can choose ATMIS, in which case they must specify the area of influence and the diversion method, that is, whether the travel information devices are in-vehicle or out-of-vehicle. If HOV lanes are selected, then stakeholders must specify HOV lane attributes that include the physical location, number

of HOV lanes, whether separated or not, time of HOV operation, and vehicle occupancy threshold for HOV eligibility.

The performance measures can be chosen directly from a (menu) list. Stakeholders must further specify characteristics of the chosen performance measure in terms of spatial, temporal, and user dimensions. If, for example, delay is chosen, then stakeholders must specify locations where the delays are needed, whether delays are needed by time of day, user group (age, gender, income), or travel decisions (mode, route).

Stakeholders must choose the relevant environment for the analysis. For example, the project location can be chosen to be a specific county, city, corridor, route, or such. PLANiTS can display a map of the region for visual selection of specific links and nodes. The environment definition identifies the data to be used for modeling.

During the specification process, intelligent advice is available. Specifically, the action base constructs a list of associated actions that enhance the performance of the primary action selected. In the HOV lane example, these can be the construction of park-and-ride facilities, construction of exclusive HOV ramps and flyovers, enforcement, advanced public transportation systems (APTS) that offer real-time ride-share matching, HOV priority parking and employer supplied ride-sharing incentives. The rules that suggest associated actions are based on theoretical and empirical evidence about compatibility. The associated actions chosen by the users can be added to the planning vector. Stakeholders must specify the associated action attributes as well. For example, the location and size of a park-and-ride lot must be specified, if chosen.

The evaluation of the planning vector, after it is specified, can proceed in several ways. Only one way is illustrated here. To calculate the performance measures, the analysis agent uses the information contained in the planning vector and suggests the use of historical cases and relevant models. Assume that stakeholders decide to examine the case-based reasoner (4).

Analogies and case studies are used extensively in planning and evaluation. PLANiTS case-based reasoner formalizes their use and provides a structure for organizing and retrieving qualitative and quantitative case knowledge. After entering the reasoner, stakeholders can adjust the matching stringency for each element of the planning vector. For example, by choosing low action fit, the action type must match; for a medium fit, an HOV case must match the number of HOV lanes to be added; and for a high fit, an HOV case must match vehicle occupancy level and number of HOV lanes. The idea is that by choosing low action specification, only the cases that have the same primary action are retrieved and displayed, whereas a high matching specification selects cases with the same numerical values as specified in the planning vector. Stakeholders can also select similar matching specifications for performance measures and the environment. For the retrieved cases, stakeholders can examine text summarizing the cases in terms of case location, action type and action attributes, performance measures evaluated, methodology used for evaluation, and the quality of the case study. Stakeholders can exclude (or include) cases from the active case list depending on their personal judgment. When stakeholders are satisfied with the similarity of retrieved cases, they can calculate the summary statistics for the performance measures (these are changes in performance due to implementation of actions). The reasoner calculates and displays the performance measure average for retrieved cases, and users can either accept or reject the result (i.e., estimated value of the performance measure). If accepted, the result is attached to the performance measure for possible retrieval later. The use of case-based

reasoning will often occur when experience with the action is scarce (e.g., currently, ITS experience is limited), and when models do not exist for detailed evaluations.

After having examined the case-based reasoner, stakeholders may wish to use the model-based reasoner for evaluation. Users can choose to run the models suggested by the analysis agent; the suggestions are based on the user-specified planning vector. When stakeholders choose a specific model, they are presented with the data requirements for the model. If the required data are available internally, then the model run can proceed (availability of data in PLANiTS is ascertained internally based on the environment vector specification). If the data items are not available, then stakeholders can either enter the unavailable items or return to the planning vector and respecify the environment vector. Currently the authors use the ComBehQ (combined behavioral and queueing) model developed by Khattak et al. (5) to evaluate ATMIS actions and a combination of *FREQ* (6) and *Minutp* (1) for HOV lane evaluations. After a model runs, the results are displayed in terms of change in performance measures due to implementation of the action. To examine trade-offs between alternative actions, PLANiTS can concurrently display the results from two separate planning vectors.

Depending on user needs, PLANiTS output can be descriptive or prescriptive. When evaluating transportation improvement actions through modeling or case-based reasoning, the output is descriptive. That is, PLANiTS estimates system performance with and without the proposed transportation improvement action. If the user requests advice on alternative transportation improvement actions or relevant performance measures, then PLANiTS provides prescriptions. The current prescriptions are simple; for instance, if the user is interested in the ISTE "congestion relief" factor, then PLANiTS suggests using delay and roadway congestion index as performance measures. Moreover, complementary transportation actions are also suggested such as adding a park-and-ride lot with an HOV lane. Ultimately the PLANiTS suggestions will become more context-specific (i.e., the environment will be taken into account in making prescriptions).

The planning vector is considered assessed when the selected performance measures have been calculated (through models or cases). The assessed planning vector can be shared among stakeholders working on separate computers. In addition, stakeholders can send and receive messages to debate various aspects of the assessed planning vector. A discussion list keeps track of communication with other stakeholders. Finally, the session is terminated when stakeholders complete the projects and resolve outstanding issues (or reach an impasse).

## APPLICATION OF PLANiTS: HOV LANE ANALYSIS

Most real-life transportation planning situations are complex. They involve several stakeholders who tackle intricate technical and non-technical issues with often limited knowledge and who go through complicated deliberation and negotiation. A real planning situation is described to illustrate the application of PLANiTS. The case study is that of the Interstate 80 expansion between the Bay Bridge and Carquinez Bridge in the San Francisco Bay Area. The decisions have already been made in this case. The purpose in presenting it is to identify areas where PLANiTS can (or cannot) support the planning process. Clearly, this is not an evaluation of PLANiTS effectiveness in a real-life planning situation, but an illustration of its potential.

## Case Description

I-80 between the San Francisco Bay Bridge and Carquinez Bridge is a severely congested commute corridor in the Bay Area. To alleviate congestion, the original project proposal developed by the California Department of Transportation (Caltrans) in cooperation with FHWA was for increased capacity by adding mixed-flow lanes, additional auxiliary lanes, and intermittent HOV segments to bypass congested areas. The project was proposed in the early 1980s and also included the modification of existing interchanges and the construction of park-and-ride lots and bus stops. Caltrans' rationale for additional capacity was avoiding congestion and Level-of-Service F along the entire route. In 1983 Caltrans completed the environmental impact statement (EIS) for the I-80 project. The Metropolitan Transportation Commission (MTC) approved the EIS in 1984 and the initial design in 1987.

To begin construction, Caltrans started collecting freeway agreements from the affected cities in the corridor, which included the cities of Albany, El Cerrito, Emeryville, Hercules, Pinole, Richmond, San Pablo, and Berkeley. However, the city of Berkeley refused to sign a freeway agreement with Caltrans in 1988 because the city council was concerned about the construction impacts, possible negative effects on air quality, scarcity of transit components in the project, and potential for inducing traffic growth, suburban sprawl, further congestion, and traffic spillover to local streets. Berkeley expanded the evaluation criteria to include air quality and other considerations. Moreover, Berkeley, Albany, and Emeryville thought that the distribution of impacts was not fair and that they would bear more of the burden of the corridor's transportation problem than other cities, which were creating more housing but not more jobs.

After objections from cities regarding growth-inducing and environmental impacts, and FHWA now desiring continuous HOV lanes rather than intermittent ones, Caltrans responded with a major redesign that would cost additional resources. The HOV lanes were made continuous. Meanwhile, Berkeley developed its own plan that included adding no new lanes or widening, converting one existing mixed-flow lane to an HOV lane, raising the Bay Bridge toll for single-occupant vehicles, providing regular mass transit commuters with free or low-cost passes for occasional use of the Bay Bridge, constructing new park-and-ride lots, instituting transit shuttles, and entertaining broader consideration of transit alternatives such as ferries and rail. They thus expanded the scope of proposed transportation improvement actions.

The I-80 project was affected by air quality concerns. The Citizens for a Better Environment and the Sierra Club sued Caltrans for failure to guarantee that highway expansion would not jeopardize air quality standards established by the Clean Air Act. They won an injunction against MTC prohibiting any highway construction until they met the requirements of the 1982 state implementation plan for air quality in the Bay Area and developed an acceptable process for determining air quality conformity. The I-80 project was directly affected by the court order. In response to the litigation, MTC adopted a resolution that articulated MTC's policy on air quality review of projects. Caltrans would now need to comply with the resolution to get MTC approval for the I-80 project. To help Caltrans develop a project that addressed the resolution and that could be implemented within budget, MTC convened a series of meetings with the representatives of Caltrans, Alameda and Contra Costa counties, and the city of Berkeley. These meetings led to the development and adoption by MTC in early 1990 of a set of objectives to guide the design of the I-80 project. Caltrans completed the environmental reevaluation, which included detailed air quality analysis.

MTC later rejected Caltrans' redesign, citing incomplete air quality analysis, a cost estimate exceeding the available budget significantly, and insufficient transit access to a BART (Bay Area Rapid Transit) station. At this point, Caltrans abandoned its designs and started all over. The I-80 project was redesigned such that it provided continuous HOV lanes in both directions and no longer included additional mixed-flow lanes. In 1991 Caltrans and FHWA approved the I-80 environmental reevaluation, which included studies on air quality, energy, geotechnical, hazardous waste, noise, right of way, socioeconomic, cultural resources, utility relocation, and visual impacts. On the basis of the results of these studies, Caltrans believed that no additional environmental documentation was required.

In 1992 the Berkeley city council rejected Caltrans' most recent I-80 project proposal. However, the city indicated a willingness to meet with Caltrans, MTC, and the local transit agency to consider a comprehensive HOV project that would meet specified conditions of approval. The negotiations resulted in a series of project assurances. However, the city of Berkeley still chose not to approve the I-80 project—partly because of the opposition of city council members to widening I-80. The city did not sign the freeway agreement. Caltrans decided to restrict the construction to the current I-80 right of way so that the construction did not affect Berkeley city streets, thereby circumventing the need for a freeway agreement from Berkeley.

The MTC finally approved the I-80 expansion project. The construction began in 1992. However, environmental groups filed suit, claiming that the EIS was not adequate and halting construction with a restraining order. The court ruled that the suit was not filed in a timely manner, and the construction began after a slight delay and is ongoing.

## PLANiTS Support

Certain observations can be made about the I-80 case study:

- Different stakeholder groups influence the decision process: (a) federal, state, and regional agencies analyzing the impacts of alternative strategies; (b) elected officials and support staff for relevant cities concerned about the interests of their constituencies; and (c) citizen's groups, each with its own special interest.
- The stakeholders' preferences change over time: for example, FHWA initially preferred intermittent HOV lanes but later changed to constructing continuous HOV lanes. Further, the planning process was long and iterative with several redesign and reevaluation cycles.
- As more stakeholders joined, the criteria for evaluation and the scope of transportation improvement actions expanded and the spatial distribution of impacts became important. Several meetings were held, and the potential for conflict (and litigation) between stakeholders increased. Negotiation was part of the issue resolution.

The PLANiTS methodology is suitable for supporting such a process because it consists of a series of mutually interdependent steps that progress toward developing transportation improvement projects. PLANiTS can iterate transportation planning cycles from project proposal development to analysis to deliberation and back to changing the project specifications. PLANiTS involves stakeholders early in the planning process and allows changes in stakeholder preferences regarding actions and evaluation criteria.

Stakeholders can (a) check for violations of certain requirements at the chosen project location, (b) ensure that the project addresses certain goals, (c) develop and refine actions, and (d) evaluate the

impacts of selected actions. During the whole process, PLANiTS facilitates stakeholders' communication and deliberation over critical issues. Moreover, users can seek PLANiTS' advice on the actions and performance measures to be considered, and models and data to be used.

Importantly, PLANiTS facilitates the systematic exchange of stakeholder preferences regarding actions and performance measures (through a "send PV" function) and more frequent and easier communication between the stakeholders (through a "deliberate" function). The processes that stakeholders may use include search and specification of transportation improvement actions, matching of selected actions with similar historical cases, and evaluation of actions using models and data. Stakeholders might also deliberate over possible actions and performance measures, debate and scrutinize issues, critique and refute propositions, warn and advise each other against certain options or outcomes, and work on answering important questions. PLANiTS provides a medium for preference and information exchange that can

- Reduce the need for formal meetings and cause those that are held to have a tighter focus;
- Organize and catalog the communications as a continuous group memory to enhance uniformity of perceptions among stakeholders;
- Estimate the impacts of proposed actions by models and case-based reasoning—for example, the city of Berkeley might examine the case base to seek qualitative information on whether converting an existing mixed-flow lane to HOV had previously sparked community conflicts;
- Use state-of-the-art models for environmental impact analysis, possibly reducing the potential for conflicts; and
- Analyze impacts at the disaggregate level, thus identifying early in the process whether certain communities will bear a greater burden than others and consider strategies to compensate affected communities.

When making major investment decisions, individuals and groups can, and often do, become antagonistic, especially when they cannot agree on certain aspects of the project. In such situations, PLANiTS can provide limited support. It can serve as a forum that allows stakeholders to dispute issues and results, bargain and haggle over aspects of projects, and compromise and settle matters while concealing information (e.g., developing private PVs) from the opponents to gain a strategic advantage. In the future, PLANiTS will address important issues associated with the political process through intelligent facilitation or arbitration; this could improve the quality of debate and working of politics in planning. However, it will not eliminate politics—some aspects of the planning process will always remain beyond the scope of PLANiTS support.

### Evaluation of PLANiTS

PLANiTS is a new methodology that is not yet field-tested. The authors have presented a conceptual structure and a simple PLANiTS model, but the true test of its effectiveness will come from implementation in real-life situations. Vlahos et al. (2) summarize a design methodology and initial ideas on PLANiTS evaluation in the organizational context. PLANiTS implementation will be phased into a real-life planning situation at the metropolitan planning organization (MPO) level. Significant refinements in PLANiTS are expected as learning occurs. It will be important to train PLANiTS users properly.

This includes education about other stakeholders who will be using PLANiTS (e.g., government agencies, citizens' groups), its purpose (decision support for planning problems), and PLANiTS functionality (e.g., modeling, case-based reasoning, and deliberation).

During the PLANiTS field testing, the authors will evaluate the relevant technical and organizational issues. Adopting PLANiTS at the MPO level will be a significant investment in a computing environment. If PLANiTS appropriately addresses the issues, then it will be valuable and worthwhile. PLANiTS' appropriateness to a planning situation will be determined from the scale and type of projects, need for transportation knowledge and modeling, and demand for communication among stakeholders.

Once PLANiTS is adopted by a planning agency, its value will depend on the quality of diagnosis, range of alternatives and impacts considered, sophistication of modeling, and overall evaluation quality. Furthermore, the success of PLANiTS in supporting stakeholder communications will be key. The functions will include coordination among stakeholders, collaboration, efficiency, and overall improvement in the quality of debate and deliberation. Given that the transportation planning process is often lengthy, PLANiTS' flexibility and its ability to learn from intermediate results will be important. Finally, differential organizational impacts of PLANiTS are expected. For example, managers may benefit from greater coordination, while analysts benefit from the models, data bases, and cases as well as collaboration with colleagues (2).

### LIMITATIONS OF PLANiTS

Perhaps some of PLANiTS' strengths are also its weaknesses. Specifically, involving stakeholders early in the planning process and improving stakeholder communication might increase the conflict potential and make the process unmanageable. Other important PLANiTS limitations are summarized here:

- Developing a fully functional PLANiTS will require significant financial and time commitment.
- PLANiTS is information-intensive. The presentation of large quantities of information to stakeholders can increase task and decision complexity.
- Current ITS knowledge is scarce, and therefore the relevant cases and models available for evaluation are also limited. The scant experience with new technologies reflected in PLANiTS may not provide a sufficiently strong basis for ITS implementation in real-life situations.
- Given the mistrust among stakeholders, there are questions about who would maintain PLANiTS.
- Complex real-life situations are fraught with divergent (rather than convergent) empirical evidence. If stakeholders find divergent evidence, then resolving issues may become difficult.

Finally, further theoretical and applied development of PLANiTS is needed. The future PLANiTS research and development will focus on refining the proposed structure and PLANiTS application in a real-life situation.

### CONCLUSION

This paper presents PLANiTS' structure and key functions. The proposed transportation projects are represented as planning vectors in PLANiTS. Through the planning vector, stakeholders can

select transportation improvement actions from the action base, performance measures from the policy base, and environment from the data base. They can then use the case-based reasoner or the model base to evaluate the impacts of actions contained in the planning vector. During the analysis process, PLANiTS users can deliberate by sending and receiving text messages and by sharing their planning vectors.

In developing PLANiTS, the authors have taken steps toward making operational a new planning methodology. This methodology seeks to be open and policy-relevant; it permits stakeholders to examine ITS and conventional action trade-offs in an interactive environment; and it unifies transportation analysis with deliberation. PLANiTS can enhance creativity in exploring innovative solutions by integrating structured models, with semistructured evaluation, such as cases and unstructured electronic support for human interactions. Future versions of PLANiTS should be capable of evaluating more actions (besides HOV lanes and ATMS) and their interactions using cases, expert rules, and models. Ultimately, PLANiTS will not change the political process; however, it could contribute to the planning process by enabling stakeholders to examine trade-offs and avoid at least some potential minefields and costly mistakes.

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